THE ORKING ENVIRONMENT FOR RESEARCH IN U.S. AND JAPANESE UNIVERSITIES:

Contrasts and Commonalities

National Research Council

The Working Environment for Research in U.S. and Japanese Universities

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Since 1985, the National Academy of Sciences and the National Academy of Engineering have engaged in a series of high-level discussions on advanced technology and the international environment with a counterpart group of Japanese scientists, engineers, and industrialists. One outcome of these discussions was a deepened understanding of the importance of promoting a more balanced two-way flow of people and information between the research and development systems in the two countries. Another result was a broader recognition of the need to address the science and technology policy issues increasingly central to a changing U.S.-Japan relationship. In 1987, the National Research Council, the operating arm of both the National Academy of Sciences and the National Academy of Engineering, authorized first-year funding for a new Office of Japan Affairs (OJA). This newest program element of the Office of International Affairs was formally established in the spring of 1988.

The primary objectives of OJA are to provide a resource to the Academy complex and the broader U.S. science and engineering communities for information on Japanese science and technology; to promote better working relationships between the technical communities in the two countries by developing a process of deepened dialog on issues of mutual concern; and to address policy issues surrounding a changing U.S.-Japan science and technology relationship.

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U.S.-JAPAN DIALOG ON THE WORKING ENVIRONMENT FOR RESEARCH IN UNIVERSITIES
Beckman Center
January 9-10, 1989

U.S. PARTICIPANTS

Roland Schmitt
(Cochairman)
Rensselaer Polytechnic Institute

Joseph Ballam
Stanford Linear Accelerator Center

Frank Carrubba
Hewlett-Packard Company

Marvin Cohen
University of California, Berkeley

William Cummings
Harvard University

Gerald Dinneen
Honeywell, Inc.

Marshall Edgell
University of North Carolina

Alan Engel
International Science and
Technology Associates, Inc.

James Merz
University of California,
Santa Barbara

Tom Owens
National Science Foundation

Howard Schneiderman
Monsanto

Nam Suh
Massachusetts Institute of Technology

JAPANESE PARTICIPANTS

Sogo Okamura
(Cochairman)
Tokyo Denki University

Jun-ichi Baba
Mitsubishi Electric Corporation

Masao Doyama
Nagoya University

Yoshihiko Ichikawa
Nagoya University

Hiroshi Inose
National Center for Science
Information System

Ken Kikuchi
National Laboratory for
High-Energy Physics

Fumio Kodama
National Institute of Science and
Technology Policy

Tsuneo Nakahara
Sumitomo Electric Industries, Ltd.

Shigefumi Nishio
University of Tokyo

Tamiya Nomura
Shibaura Institute of Technology

Michiyuki Uenohara
NEC Corporation

Justin Bloom of Technology International assisted with preparations for the meeting and the report and contributed to the discussion.

Preface

Universities play at least two very important roles in science and technology in the United States as well as in Japan. In addition to educating their nations' scientists, engineers, researchers, and future science educators, universities in both countries are a major source of basic research. Although they perform only a small portion of their nations' total research and development (R&D), they are the primary source of *basic* research for both countries.

There are, nevertheless, important differences in the way each nation's universities execute their dual roles. These differences are apparent not only in the focus, funding, and organization of research, but also in the degree of significance attached to their educational roles.

The Office of Japan Affairs of the National Research Council is organizing a series of workshops on the differences and similarities in the working environment for research in Japan and the United States with the support of a grant from the U.S.-Japan Foundation. Understanding these differences is essential to American scientists and engineers to improve access to Japan's research system, and to expand mutually beneficial collaboration between the two countries.

The bilateral dialog on "Coexistence in a Technological World: Cooperation and Competition in R&D" consists of three workshops, focusing in turn on universities, bridging organizations, and corporations as research settings. Each workshop brings together senior scientists, engineers, and others involved in and concerned about research and development in the two countries. The first workshop on university laboratories was held January 9-10, 1989, at the Beckman Center, the West Coast facility of the

National Academies of Sciences and Engineering. The discussions focused on the culture of academic research, large university research laboratories, university-industry relations, and the experiences of foreign researchers in the United States and Japan.

This paper was prepared by the Office of Japan Affairs as background information for the dialog.

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1
Introduction

As educators of future scientists, researchers, and engineers, and as the performers of the "freest" form of basic research in both countries, universities are in a position to play an important role in efforts to open doors for new exchange opportunities. A comparison of the U.S. and Japanese university research systems, however, uncovers numerous obstacles to foreign access. Although most are not consciously erected barriers, they appear, nonetheless, to have had significant impact and thus call for increased understanding and efforts at rectification.

A review of the literature indicates that the U.S. and Japanese university research systems are facing similar pressures and challenges, including the rising costs of research, shorter lag times between basic and applied research, the need for more multidisciplinary research, the dual challenge of education and research, and defining the government's role in resource allocation in university laboratories. Efforts to meet these challenges have brought about movement in both countries toward more university-industry cooperation, a development that creates an additional challenge when conflicting academic and corporate principles meet. Japan faces an additional challenge in the need to improve its basic research capabilities.

Many of the factors that affect foreign access are rooted in organizational differences between the two nations' university research systems, a fact that is likely to make it difficult to eliminate them through formal negotiations between the United States and Japan. Varying degrees of researcher independence, different approaches to funding, language barriers, different definitions of the meaning of "basic" research, and differing levels of domestic support for overseas research are but a few factors that may

hamper the integration of foreign researchers into a Japanese university laboratory.

Both nations' systems have strengths and weaknesses, and both nations are in the process of addressing their perceived weaknesses. Neither is in a position to claim that it cannot learn from the other, but both will lose if the effort is not made.

The following pages compare and contrast university research and development systems in the United States and Japan. While it is possible to make some generalizations about the nature of each country's system, it should be remembered that great diversity exists across both nations' university laboratories. The major goal of this review of the literature is to highlight factors likely to affect foreign participation and access. This preliminary assessment is meant to serve as a basis for discussion and future study, rather than a definitive statement.

SCOPE

Although there are a large number of universities, colleges, and academic research institutions in the United States and Japan, significant research work in both countries is concentrated in a relatively small number of organizations.

Japan's major universities are usually categorized by funding source: national, private, and public or local. Japan's 96 national universities and their associated research institutes are the heart of the university research system. Most national universities are the most prestigious, sharing their rank with a very few select private universities. Since national universities tend to be older than public or private ones, they also tend to be more traditional in organization, a subject that will be discussed in more detail below. While technical colleges have gained some credibility in recent years, junior colleges remain largely the domain of female students majoring in home economics.

U.S. universities are similarly divided between public and private, based primarily on source of funds, although there are no civilian universities in the United States that are funded by the federal government. (There are, however, three federally-funded military academies.) There is also less of a clear "prestige" distinction in the United States, where a list of the most respected schools includes both private and public institutions. Only 100 U.S. universities are considered "research universities."

In both the United States and Japan, a large portion of university research and development money is concentrated in the natural sciences and engineering (see Table 1-1). In Japan, however, R&D expenditures in engineering fields make up a larger share of the total. The relatively high Japanese expenditures in the social sciences and "all other fields" probably

TABLE 1-1 Expenditures for Research and Development (R&D) by Higher Education in the United States and Japan, 1986 (constant 1982 dollars)

Category	United States	Japan
Total expenditures for R&D by higher education	$12,656,000,000	$7,297,000,000
Share of total R&D performed by higher education	12.0%	20.0%
Breakdown by field		
Natural sciences	43.2%	9.0%
Engineering	14.6	20.7
Agriculture	10.8	4.8
Medical sciences	23.7	25.5
Social sciences	5.8	13.0
All other fields	1.9	26.9

NOTE: Japanese dollar figures were calculated by the National Science Foundation (NSF) using Government of Japan, Management and Coordination Agency information. "All other fields" includes home economics, education, arts, and others. The United States does not consider work in most of these fields to be "scientific research." The expenditure figures include salaries, for both U.S. and Japanese university researchers.

SOURCE: NSF, The Science and Technology Resources of Japan: A Comparison with the United States, 1988, 60.

reflect the even distribution of general research funds and the relatively high number of faculty members in those areas.

In Japan the high concentration of graduate education in the national universities can be seen in the fact that these universities grant 63 percent of all graduate degrees. Historically, the concentration of *engineering* Ph.D.s has been even more stark. From 1957 to 1983, for example, national universities awarded 85 percent of all engineering Ph.D.s in Japan.[1] In the United States, too, the 100 "research universities" produce a majority of the nation's Ph.D.s in science and engineering.[2]

[1] Lawrence P. Grayson, "Technology in Japan: Advancing the Frontiers; Part 1: Graduate Education, " *Engineering Education* (April/May 1987), 690.

[2] Office of Technology Assessment, *Educating Scientists and Engineers*, 1988, 72.

2
Organization and Funding

When comparing U.S. and Japanese R&D expenditures by performer, one may erroneously conclude that Japanese universities play a significantly greater role than their American counterparts (see Table 1-1). A large amount of money spent on Japanese university research and development, however, supports research in fields other than the natural sciences and engineering. In addition, while there are Japanese university laboratories in which excellent research is being conducted, the Japanese university research system does not display the breadth or degree of excellence in basic research found in U.S. universities. The direction and amount of overall funding, however, only partially illuminate the differences between the U.S. and Japanese university research systems.

Organizational differences affect how each nation meets the challenges of scientific and technological research as well as the extent to which a foreign researcher is able to "fit in" to the university laboratory setting. Japanese university research is generally seen as more group-based, hierarchically organized, and directed than that in the United States; this rigidity is reinforced by Japan's traditional university research funding system. American university researchers, particularly younger researchers, by contrast, are more independent and more mobile, and the American system of independent funding reinforces that tendency.

The fundamental unit of organization in a traditional Japanese national university is the chair (*koza*). Chairs are grouped for administrative, teaching, and research purposes into departments. They are generally small and numerous. A typical chair might consist of one professor, two or three assistant professors, and several lecturers, assistants, and technicians, and of

course, students. Based on a 1988 survey of 323 *manufacturing engineering* chairs, the average research team in that field numbers slightly less than three people, not including students.[1]

Having automatic lifelong tenure, the chaired professor has extensive authority over his research team, assigning research projects and selecting all new members. Master's and Ph.D. applicants must be accepted by the chaired professor to pursue work in a particular field and their thesis research must support that of the chair's. Graduate students and young researchers succeed by supporting the work of their superiors worldwide, but particularly in Japan.

The hierarchically organized chair system contrasts with the larger hierarchy of university administration, which can be characterized as one of "feudal lords" without a leader. Thus, while each chair is highly centralized, university administration in the national universities tends to be fragmented. Because the success of each chair depends to a large extent on the ability of the chair to work well as a team, competition among chairs for new assistants and the most able students is intense.

It would be a mistake, however, to assume that the chair system as described above is representative of *all* of Japan's universities. Many of its newer private universities created after World War II are organized more along the lines of the American university. In these universities, decision making is more likely to be centralized at the university administration level. In addition, efforts are being made within some national universities as well. One of the newer national universities in Tsukuba, for example, has been modeled on the American university department system. Finally, some university chair systems may be more rigid than others. Engineering schools, in particular, tend to be, by the nature of their research and the requirement that it be relevant to the world outside academe, more flexible. In addition, some chairs have shown flexibility in shifting to new areas of research.

The Ministry of Education, Science, and Culture (Monbusho) is responsible for financing national university expenditures and, to a lesser extent, supporting private and public universities. National university professors are considered civil servants and their salaries are paid by Monbusho. Most research funds are distributed via the chair system described above. In this way, the central government exercises considerable control over Japanese national university activities.

[1] Kazuzaki Iwata, *Manufacturing Engineering: University-Industry Coordination*, presented at the second Japan-U.S. conference on manufacturing research, July 11-14, 1988.

Three categories of funds are made available to Japanese national universities:[2] (1) general research funds determined by a standard formula, (2) special research funds for facilities and equipment necessary for specific research projects, and (3) grants to researchers or groups of researchers who apply for them through a competitive process. Monbusho also provides fellowships and travel grants.

The first form of support is provided to all national universities for general research funds. The amount of support is calculated by a standard formula aimed at guaranteeing a minimum level of support to each researcher in the national university system. The formula accounts for the number of chairs or researchers, the nature of the research (e.g., whether it is experimental, nonexperimental, or clinical) and whether or not the chair is in charge of graduate courses. Funds are channeled through the chair system, thus reinforcing the authority of the chair. Although in principle the university can distribute these funds among its chairs as it sees fit, in practice the university itself uses a standard formula to divide the funds democratically.

The second form is offered as special research funds for facilities and equipment. These funds are granted as available based on the university's own priorities.

The third form of support, known as Monbusho's grants-in-aid for scientific research program, is open to all Japanese universities. Under this program research grants are awarded directly to researchers (individuals or groups) upon approval by the appropriate committees within Monbusho's Science Council. According to Monbusho, these grants are generally approved for basic research that is expected to make important contributions to scientific progress. In 1986 Monbusho granted 43.5 billion yen ($272 million), about 13 percent of its scientific research budget, under this program.[3]

Private and public universities are only partially supported by Monbusho, in the form of block grants, provided to subsidize professors' salaries. Using a standard of recurrent expenses set by national university budgets, Monbusho's stated policy is to try to provide half. According to a recent newspaper editorial, however, Monbusho's private education subsidies have not exceeded 20 percent of private university operating expenses since 1985.[4] Monbusho also gives grants to public and private universities for facilities and research equipment.

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[2] Lawrence P. Grayson, "Technology in Japan: Advancing the Frontiers, Part 2: Research and Development," *Engineering Education* (April/May 1987), 700-702.

[3] Ministry of Education, Science and Culture, *The University Research System in Japan*, 1986, 1.

[4] "Shigaku Josei wa Zogaku shi Genkaku ni," [Increase Private Education Assistance Sharply] *Nihon Keizai*, December 5, 1988, 2.

Although American universities, like their Japanese counterparts, are organized by departments that correspond with scientific disciplines, decision making tends to be less centralized within the department. As in Japan, research is usually conducted in small groups, but it need not be initiated by the department head. The higher degree of research autonomy in the American university laboratory is probably due to a combination of cultural and systemic factors. For one thing, American academic research is based more on individual efforts than is the case in Japan. American researchers are permitted to pursue their own area of interest as long as they can find funding. The fact that each researcher is responsible for finding his own external funding reinforces the decentralized nature of university research, as different sources of funding may call for varying agendas within one laboratory or even by one researcher.

Nevertheless, a decentralized system does not *necessarily* foster the most creative, new research, and there are subtle, informal pressures in the U.S. system that also serve to direct the nature of research. The U.S. requirement that a researcher find his own funding may, in fact, discourage researchers from pursuing research that sponsoring organizations judge to be less important. American university researchers, constantly faced with the task of finding new funding, may "freely choose" to pursue "acceptable" (i.e., "fundable") research. In other words, whereas the Japanese researcher may be formally obligated to pursue research directed by the chair, the U.S. researcher may be encouraged to pursue research that is likely to receive funding. American university researchers are rewarded in the form of promotions and tenure (which is automatic in the Japanese case) based on "scientific productivity," generally measured by the number of publications they produce in their field, and by the degree to which they are recognized by colleagues in their discipline. Furthermore, in the United States, internal resources (e.g., laboratory space) are allocated by the department head who bases his decisions on quality of research, scientific interest, and the prospects for obtaining external support.

In both the United States and Japan, the university research funding systems can discourage young researchers. In Japan, the hierarchical nature of the seniority system provides researchers with access to more funding as they gain seniority. In the United States, proposals that must be completed to apply for government research funding can put less experienced researchers at a disadvantage. Both governments require that anticipated results of research be included in proposals for research funds. This requirement has led professors in both nations to submit proposals for work already in progress, a practice that young researchers seeking initial funding can take advantage of only through their associations with senior researchers already engaged in research.

Although the U.S. federal government has long been the greatest patron of American university research, there is no federal agency, with the exception of the National Science Foundation (NSF), that plays the role of allocating general research funds played by Monbusho in Japan. In 1985 NSF provided only about 16 percent of the federal support made available for academic research and development.[5]

Government support of university research in the United States is much more mission-oriented than that in Japan. In 1985 over 90 percent of U.S. federal support for academic research and development came from the combined efforts of six agencies: National Institutes of Health, National Science Foundation, U.S. Department of Energy, U.S. Department of Defense, National Aeronautics and Space Administration, and U.S. Department of Agriculture.[6] With the exception of NSF, each of these agencies is mission oriented. Virtually *all* U.S. federal support for university R&D is, like Monbusho's grants-in-aid program (which, it will be remembered, accounts for only about 13 percent of Monbusho's research budget), provided for specific research projects. The government awards research grants or contracts to a university to carry out a particular project.

[5] National Science Foundation, *Science and Engineering Indicators–1987*, 245.

[6] National Science Foundation, *Science and Engineering Indicators–1987*, 245.

3
The University Role: Research or Education?

Universities in both nations have dual roles—research and education. Despite Monbusho's focus on the educational role of the Japanese university, industry in Japan has taken over the training role to a much greater extent than is the case in the United States. It is debatable whether industry trains its new employees to the extent that it does because universities fail to do so, or whether universities do not conduct such training because industry prefers to train its own employees. It is, nevertheless, true that considerable training and education in Japan occurs in the corporate rather than university environment.

The Japanese student's "university experience" is very different from that of his counterpart in the United States. The so-called "examination hell" created by the Japanese educational system for its university-bound high school students has, perhaps, been overplayed by the media. It is nonetheless true that Japanese high school students spend many more hours studying than do their American counterparts, motivated in part by difficult university entrance examinations. By contrast, therefore, their university years are often viewed as a respite. In many ways, higher education is considered the weakest link in Japan's education system.[1] At best, the university experience is a time for individualized learning. At least, it offers

[1] *Sogo ni Mita Nichi-Bei Kyoiku no Kadai: Nichi-Bei Kyoiku Kyoryoku Kenkyu Hokokusho* [Tasks for Education in Japan and the United States: A Binational Perspective, Report of the Cooperative Research Project on Education in Japan and the United States], Amagi Isao, ed. (Tokyo: Daiichi Kokushuppan, 1987).

the student a chance to develop social skills that were ignored during the strenuous high school years. Few students who manage to enter a Japanese university fail to graduate.

The contrast between the weary Japanese high school student and the carefree university student is almost reversed in the United States, where many college freshmen discover that high school has not prepared them for the serious study and heavy workload expected by the university. American industry relies heavily on universities to train students, to provide them with the information, habits, and discipline required in their chosen careers. There is considerably less pressure and competition to enter universities in the United States than in Japan; in the United States, the competition and pressure are encountered between entrance and graduation. Attrition rates are correspondingly higher in the United States than in Japan.

Research and educational functions are not usually as well integrated in Japanese universities as they are in their American counterparts. In Japan, university-affiliated research institutes often have separate faculties appointed exclusively for research functions. Although Monbusho states publicly that the primary function of Japanese universities is to educate, there have been calls for closer integration between the two functions in order to improve both. Tokyo Institute of Technology Professor Eiji Oshima, for example, recently told a U.S.-Japan forum that the most important function of the Japanese university is research, because education requires hands-on research.[2] Lawrence Grayson has also argued that because research is an important element of *graduate* education, it may be necessary to integrate research and education to improve and expand graduate education in Japan.[3]

In 1984 there were 7,477 doctoral degrees conferred in Japan; the United States granted 32,971 in 1985.[4] Although the percentage of those degrees offered in the combined fields of natural science and engineering is about the same in both countries, the split *between* natural sciences and engineering is illuminating (see Table 3-1). The share of total Ph.D.s granted in the natural sciences in the United States is more than twice the corresponding share in Japan, whereas the share granted in engineering is significantly less than that in Japan.

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[2] Eiji Oshima, "The Role of Engineering Education in the Japanese Society," *Proceedings of the Fourth United States-Japan Science Policy Seminar*, Edward E. David and Takashi Mukaibo, eds. (Washington, D.C.: National Science Foundation, 1988), 40.

[3] Lawrence Grayson, "Japan's Intellectual Challenge: The Future," *Engineering Education* (February 1984), 28.

[4] National Science Foundation, *The Science and Technology Resources of Japan: A Comparison with the United States*, 1988, 61.

TABLE 3-1 Doctoral Degrees by Field and as a Percentage of Total

	Japan (1984)		United States (1985)	
Field	Number	Percentage of Total	Number	Percentage of Total
Natural sciences	807	10.8	7,793	23.6
Engineering	1,291	17.3	3,251	9.9
Agriculture	614	8.2	1,057	3.2
Other	4,765	63.7	20,871	63.3
Total	7,477	100.0	32,971	100.0
Total, science and engineering	2,712	36.3	12,101	36.7

SOURCE: Percentages calculated from numbers in: National Science Foundation, The Science and Technology Resources of Japan: A Comparison with the United States, 1988, 61.

Also important to Japan's success in "catching up with the West" has been the even greater share of Japanese *undergraduate* degrees in engineering. Japan, with just over half the U.S. population, graduates close to the same number of first-degree engineering students as does the United States. These students also account for a significantly larger share of total undergraduate degrees in Japan (see Table 3-2). Relatively few of Japan's undergraduate engineers continue their formal education. Most join corporations soon after completing their first degrees. These students have been able to move directly into industry to apply their engineering skills to manufacturing. As the Japanese move into new and rapidly changing fields, however, they are beginning to perceive a need to generate knowledge of their own, and, as a result, they are becoming increasingly concerned that only a small share of engineering undergraduates go on to pursue graduate engineering education. A recent report to Monbusho called for "efforts [to be] made to gradually increase the number of people completing the courses of masters or doctors."[5]

At the same time, because of the way some Ph.D.s are granted in Japan, not all of them contribute to the country's basic research base or pool of potential educators. Although some Japanese Ph.D.s are granted via the same approach used in the United States (i.e., university coursework, followed by examinations and a dissertation), many are granted via another

[5] Ministry of Education, Science and Culture University Chartering Council, "The Systematic Planning and Administration of Higher Education in Japan after 1986," 1984, 27.

TABLE 3-2 First University Degrees by Field and as a Percentage of Total, 1985

Field	Japan		United States	
	Number	Percentage of Total	Number	Percentage of Total
Natural sciences	12,698	3.4	120,168	11.3
Engineering	71,396	19.1	77,871	7.3
Total	373,302	100.0	1,066,439	100.0

SOURCE: Percentages calculated from figures in: National Science Foundation. The Science and Technology Resources of Japan: A Comparison with the United States, 1988, 60.

channel, known as *ronbun hakushi*, or "dissertation only" degrees. Without ever attending a doctoral level course or passing an examination, many Japanese not even enrolled in a university receive their doctorates by having their written research work accepted by a university faculty. In this way, Japanese industry researchers working on applied research for their employers receive Ph.D.s. These Ph.D. earners are probably better suited to doing excellent and efficient applied work.

A striking difference between the two countries is the large number of foreign-born students in the United States. The proportion of foreign students is greatest in U.S. graduate schools. Over half of the engineering students in U.S. graduate programs are foreign citizens.[6] Although most of them are here on temporary visas, many choose to stay after graduation and become U.S. citizens; most of those who stay remain in academe. Japanese students, on the other hand, usually return to Japan on completion of their studies here. Although there are a significant number of foreign students in Japan, most graduate engineering degrees are granted to Japanese citizens.[7] Those foreign students who earn degrees in Japan also tend to return to their native countries upon graduation.

The inclusion of foreign engineers in American university research has many positive aspects, including the infusion of new talent, diversity, and much-needed supplemental technical manpower. The high proportion of foreigners in graduate engineering programs, however, also generates some concern. Most important, the proportions reflect a correspondingly

[6] National Science Foundation, *Science and Engineering Indicators—1987*, 196.

[7] Lawrence P. Grayson, "Technology in Japan: Advancing the Frontiers, Part 1: Graduate Education," *Engineering Education* (April/May 1987), 691.

low interest among U.S.-born students in graduate engineering education, some of the reasons for which are discussed below. In addition, concerns have been raised about the possibility that U.S. educational standards are being lowered by the increasing number of foreign teaching assistants who lack a proper mastery of English, the possibility that foreign teaching assistants of different cultural backgrounds may be discouraging women and minorities, and the possibility of future inadequacy in the supply of native engineers for national security work.[8]

Despite the large number of Japanese *researchers* coming to the United States (more than 23,000 in 1986), Japan does not account for a large share of foreign engineering *students*. Although Asia accounts for 42 percent of the foreign engineering students in the United States, Japanese engineering students make up less than 2.5 percent. Of the foreign recipients of U.S. engineering Ph.D.s, Japanese students receive only 1.39 percent.[9] There are, however, a number of large Japanese corporations with formal research training programs that include support for research abroad, at times in American universities. Japanese researchers and engineers may be working in or visiting U.S. universities, national laboratories, or industry, but they do not represent a significant share of foreigners earning degrees here.

Both the United States and Japan seem to be suffering from a lack of student interest in graduate engineering education and experts in both countries are concerned about salary gaps that encourage new engineers to move to industry, perhaps to the detriment of university research and education. During an investigation of the shortage of engineering faculty in U.S. universities, the American Electronics Association discovered that U.S. students with a bachelor's degree in engineering preferred to move into industrial employment rather than spend more money to pursue their education and then take a lower-paying job in a university. Engineering Ph.D.s in academe were reportedly making 30 to 50 percent less than bachelor degrees in industry.[10]

In Japan, Kobe University professor Kazukai Iwata recently warned that, despite the shortage of graduate engineers, an increasing number of *Japanese* undergraduates were also opting to proceed directly to work. According to Iwata, this trend is reinforced by the fact that, in general,

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[8]National Academy of Engineering, *Foreign and Foreign-Born Engineers in the United States* (Washington, D.C.: National Academy Press, 1988).

[9]National Academy of Engineering, *Foreign and Foreign-Born Engineers in the United States* (Washington, D.C.: National Academy Press, 1988), 55-56.

[10]Pat Hill Hubbard, "Internationalization of Engineering," *Proceedings of the Fourth United States-Japan Science Policy Seminar*, Edward E. David and Takahashi Mukaibo, eds. (Washington, D.C.: National Science Foundation, 1988), 162.

only large corporations employ Ph.D.s.[11] In 1982, Monbusho reported that one in seven engineering Ph.D. graduates were unemployed;[12] by 1984, the number had reached one in four.[13] It is generally believed that Japanese companies prefer to hire young workers and train and educate them themselves, rather than hire older, more educated but sometimes less adaptable workers. While it is true that some of the unemployed Ph.D. graduates in Japan are on postdoctoral fellowships waiting for a suitable university faculty position to become available, it is unclear how many of these fellowships have been created purely for the purpose of utilizing unemployed Ph.D. graduates.

[11] Kazuaki Iwata, *Manufacturing Engineering: University-Industry Coordination*, presented at the second Japan-U.S. conference on manufacturing research, July 11-14, 1988.

[12] Lawrence P. Grayson, "Japan's Intellectual Challenge: The System," *Engineering Education* (January 1984), 18.

[13] Lawrence P. Grayson, "Technology in Japan: Advancing the Frontiers, Part 1: Graduate Education," *Engineering Education* (April/May 1987), 692.

4
Basic Versus Applied Research

Despite a lack of agreement on the definitions of basic and applied research, some general observations can be made about relative strengths and weaknesses in Japan and the United States and about the role of the university laboratory in basic and applied research. It should be remembered when considering this issue that Japanese "basic" research, particularly the basic research conducted by industry, is generally considered to be more goal-oriented than U.S. "basic" research.

In both the United States and Japan, there is a division of responsibilities between universities and industry, with academe generally participating in more basic research and industry pursuing applications. In both countries, however, there is also a trend toward the encouragement of more cooperation across sectors, a subject that will be examined in some detail below.

The overall division of national research and development funds between basic, applied, and developmental research in both countries is also similar. Nevertheless it is generally accepted that while the United States leads the world in basic research, Japan's strengths are in applications. As a result, each nation has made efforts to correct what it perceives as its own area of weakness.

Now that Japan has "caught up" with the West in many fields, Japanese officials have begun to focus on the need for more basic research. The Science and Technology Agency's (STA) 1983 white paper, for example, noted that Japanese companies believe they are lagging behind their foreign competition in their ability to acquire and develop new knowledge. Then, in 1984, the Prime Minister's Council on Science and Technology called

for more basic and fundamental research. More recently, the Ministry of International Trade and Industry's (MITI) first white paper on industrial technology gave the nation good grades on high technology development, but lamented that Japan is lagging behind in basic research.[1] In these and other fora, Japanese analysts decry their inability to engage in creative fundamental research. At the same time, the Japanese believe it will become increasingly difficult to access new knowledge from abroad, according to a 1985 NSF report. NSF reports that Japanese businessmen are increasingly concerned about the availability of new information, in addition to being skeptical about the usefulness of imported knowledge given the rapid pace of advance in many of science and technology's newer fields.[2]

The United States, on the other hand, has begun in recent years to reexamine its own university education and research programs. Although a consensus has not been reached on the proper course for U.S. university research, some U.S. analysts criticize American university research programs for being skewed too much toward fundamental or basic research. The importance of science to national economic strength, however, suggests the need for continued excellence in basic research.

It should be noted, however, that the United States has achieved its world-renowned position in basic research *in spite of* research and spending policies that, in large part due to an emphasis on defense, are skewed *away* from basic research. Although universities conduct over half of the nation's basic research, university research only accounts for about 12 percent of the nation's total research and development expenditures. In contrast, more than 70 percent of the nation's research and development budget is allocated for defense. The U.S. Department of Defense's research budget is actually allocated for "research, development, testing and evaluation," or "RDT&E." Over 90 percent of its RDT&E budget falls into the "DT&E" categories.[3] This is not, of course, to belittle the amount that is spent on basic research in absolute terms. Despite the small *relative* size, the U.S. Department of Defense spent more than $800 million on basic research in 1985.

[1] Tsusho Sangyosho [Ministry of International Trade and Industry], *Sangyo Gijutsu no Doko to Kadai*, [Trends and Topics in Industrial Technology], 1988, 35, 45.

[2] National Science Foundation, Tokyo Report Memorandum, No. 69, 25 March 1985.

[3] American Association for the Advancement of Science, Report XII, R&D FY 1988, 7, 9.

5
Industry-University Cooperation

Although in financial terms Japanese industry's support for *overall* national research and development is roughly similar to that of the Defense Department in the United States, industry does not play a major role in direct support for *university* research in either country (see Table 5-1).

The recent trend toward increased university-industry cooperation is not a new phenomenon in either country. In both the United States and Japan there was strong cooperation between industry and universities before World War II. For various reasons outlined below, both nations saw a decline after the war in university-industry cooperation. Again, for reasons unique to each nation's perception of its own weaknesses, this cooperation has begun to rise again in recent years.

In the postwar United States, industrial support for university research was supplanted by the federal government. Increased federal attention to the importance of science after the success of the Manhattan Project, the "shock" of *Sputnik*, and the unusual "contract" negotiated between the government and the nation's scientists led to strong government support for basic scientific research in American universities. The split between basic and applied research responsibilities, combined with academic mistrust of the stability of research support by business, widened the rift between industry and universities.

Likewise, in postwar Japan, there emerged a strong antibusiness sentiment on university campuses, in part because many businesses were associated with the war effort. In addition, industry research and development activities were strengthened after the war and industry stopped depending on universities for scientific expertise. These factors, combined with

TABLE 5-1 Research and Development (R&D) Funded by Industry, 1986

	Percentage of National R&D Funded by Industry	Percentage of University R&D Funded by Industry
United States	48.4	6.2
Japan	74.7	2.6

SOURCES: Science and Technology Bureau, Science and Technology Agency, Indicators of Science and Technology, 1987, 6-7; National Science Foundation, Science and Engineering Indicators--1987, 243; National Science Foundation, National Patterns of Science and Technology Resources: 1987, 39; National Science Foundation, The Science and Technology Resources of Japan: A Comparison with the United States, 1988.

Monbusho rules prohibiting national university professors (who are considered government employees) from receiving funds from industry, created distance between industry and academe.

Although fear of encroachment on academic freedom probably continues in some sectors of the academic communities of both nations, and although industry continues to complain about academe's insensitivity to industrial needs, it is clear that in both nations industry and universities (with governmental encouragement) are experimenting with new ways of cooperation. Rising international competition and a recognition that in some fields basic research can lead quickly to applications have convinced some companies of the benefits of investment in basic research. At the same time, the increasing costs of conducting scientific research and federal budget restrictions have led universities to seek new sources of funds.

U.S. industry funding for university research has increased in recent years. Industry funding at the Massachusetts Institute of Technology (MIT), for example, has risen 20 percent a year since 1976 and now amounts to about 15 percent of the university's on-campus research expenditures.[1] Overall industry funding for university research rose from 3.3 percent to over 6 percent during the decade beginning in 1976.[2]

Japanese industry funding of U.S. university research has also attracted considerable attention. According to NSF, in 1982 Japanese industry spent in and/or contributed to foreign universities twice as much money as it did

[1] "Changing Relationship Seen in New Corporate-University Ties," *Nature* 335 (September 1988), 106. This share is significantly reduced if funding for research, much of which is supported by the government, at Lincoln Laboratory is included.

[2] National Science Foundation, *National Patterns of Science and Technology Resources: 1987*, 39.

in domestic ones (34 billion yen versus 17 billion yen).[3] According to a recent survey conducted by the U.S. Government Accounting Office (GAO), more than one-third of the top 150 universities in the United States (based on research spending) received funds from Japan in 1986. Japanese funding accounted for 13 percent of these universities' total foreign funding.[4] *Business Week* estimated that Japanese research contracts with U.S. universities amounted to $30 million in 1988. Some universities also received considerable Japanese industry sponsorship in the form of gifts. MIT, which has 19 Japanese-endowed chairs, has attracted particular media attention.[5] Although Japanese industry also supports Japanese university research and development indirectly, these trends in Japanese funding reflect the high quality of research in U.S. universities.

The U.S. government has encouraged university-industry cooperation to take better advantage of basic research being conducted in the nation's university laboratories—to bridge the gap between the basic research being done in university laboratories and the applications required by industry. NSF, for example, has an ongoing program in which it provides seed money to university research projects with the expectation that within five years they will be supported by industry. There are about 40 such cooperative ventures under way, about 10 of which have passed the five-year "success" mark. A newer development has been NSF's Engineering Research Centers (ERC). According to a recent GAO report, it is still too early to evaluate the overall effects of the ERC approach; industry continues to lament a lack of influence on the research agenda and direct research collaboration is limited, but over half of the industrial participants intend to continue their participation.[6] In addition, the 1986 Tax Reform Act introduced a 20 percent tax credit for corporations which contract for basic research with universities.

In the United States, start-up venture capital companies often bridge the gap between the basic research of universities and the commercialization of technology. This is especially true in newer fields, such as biotechnology. Always under financial pressure, however, many of these companies do not survive and are forced to sell their technology. In Japan, where venture capital companies are less common, industry has become a ready purchaser of U.S. high technology start-up companies.

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[3] National Science Foundation, Tokyo Report Memorandum, No. 69, 25 March 1985, 2.

[4] U.S. Government Accounting Office, *R&D Funding: Foreign Sponsorship of U.S. University Research* (March 1988), 15, 25.

[5] "On the Campus, Fat Endowments and Growing Clout," *Business Week* (11 July 1988), 70; updated information provided by MIT by telephone.

[6] U.S. Government Accounting Office, *Engineering Research Centers: NSF Program Management and Industry Sponsorship* (August 1988).

The Japanese government is also encouraging university-industry cooperation, but a central theme in Japanese policy statements is the intention to boost *basic* research. The 1982 Special Commission on Administrative Reform report called for stronger links among the educational and industrial sectors. Cooperation has also been stimulated through government research programs, which are often headed by university professors and carried out in industrial laboratories. One example is the Exploratory Research for Advanced Technology (ERATO) program, sponsored by STA. Researchers in this rather modest but much-publicized program are drawn from universities, industry, and government, as well as foreign countries. The creation of Tsukuba Science City was another governmental attempt to bring industry and universities closer together, as was the establishment of the Research Development Corporation of Japan (JRDC).

In addition, Monbusho has begun to relax its restrictions on industrial support for national universities and has even created some programs to encourage such support. Although there is disagreement about the degree to which the old restrictions actually hindered university-industry cooperation, there is no doubt that such cooperation has been made somewhat easier just by virtue of the fact that it is now "blessed" by the government.

Those who argue that Monbusho's changes are primarily cosmetic point to examples of past *indirect* support of university research by industry. Industry has often, for example, loaned or made equipment available at low prices to universities or allowed the use of its own facilities by university researchers. It has also been popular for companies to contribute small sums to professors working in areas of interest (although their interest may have been more in the professor's recommendations of students for post-graduate employment than in the actual research). In addition, according to NSF, national university professors have always been able to work for industry under the auspices of a nonprofit agency such as the Industrial Research Institute, "founded as a means to allow professors to do work for industry or for government agencies other than Monbusho."[7] Finally, Monbusho restrictions applied primarily to national universities; private universities have always been able to write their own rules on university-industry cooperation, and public university professors often give courses to local businessmen under the sponsorship of prefectural research institutes funded by MITI.

On the other hand, those who consider Monbusho's changes to be a major advance point to traditional restrictions on national university professors—restrictions that prevented them, as civil servants, from accepting the type of contract research that is common in the United States. It

[7] National Science Foundation, Tokyo Report Memorandum, No. 69, 25 March 1988, 1.

is argued that significant research cooperation through the type of indirect channels mentioned above has only been an option for the most well known professors in the best universities. The current contract research system in Japan allows national university researchers to carry out research with funds from external sources. In 1982 national universities received 2.4 billion yen to conduct 1,324 research projects on contracts. Although 78 percent of the *funds* came from government or public research institutes, a large number of *researchers* came from industry—694, compared to only 67 from the government.[8]

In addition, Monbusho has created a set of rules governing four programs under which industry can support national university research:[9]

1. The contribution reception—or donation—system, whereby industry funds a professor who incurs no obligations to the company. The professor manages the funds the same way he manages government funds. Beginning in 1987, private organizations were permitted to donate entire institutes or chairs to national universities for a two to five year renewable period.
2. The project reception—or contract research—system, whereby a professor and company agree to a research theme. Research is carried out by the university, funded by industry. By 1985, there were 1,700 total contract research projects amounting to 3.5 billion yen received by universities.
3. The research and fund reception—or contract researcher—system, which allows the exchange of both funds and researchers. The university and industry develop a cooperative research project on a common theme and industry sends funds *and* researchers to the university. Projects undertaken under this system may be supported by the government when it deems the project particularly important. In 1985 there were 842 contract researchers in Japanese universities, 85 percent of whom came from industry.
4. The cooperative research center system. Once a project is formally accepted by a joint university-industry center, it can receive funds from the government for equipment. In the first two years of the Joint Research Program, Monbusho spent 265 million yen and industry spent 1.15 billion yen on 216 projects. According

[8]M. Nishio, "New Movement in University Industry Cooperation" (Tokyo: Ministry of Education, Science, and Culture, 1983), 10.

[9]The following information has been compiled from several sources, including: Kazuaki Iwata, *Manufacturing Engineering: University-Industry Coordination*, July 1988; National Science Foundation, Tokyo Report Memorandum, No. 158, 8 July 1988; Ministry of Science, Education, and Culture, *Research Cooperation Between Universities and Industry.*

to Monbusho, there were 396 such projects in the period from April 1987 to April 1988.[10]

Monbusho also offers assistance in presenting research results and parts of its grants-in-aid program have been revamped to encourage university research that is more useful to industry (more on this below).

NSF has presented a useful classification of Monbusho's program, looking at the options by source of funding as follows:

- Industry and university share the costs. In most cases industry provides more cash, while the university provides facilities and equipment.
- Industry foots the entire bill. The university makes facilities and equipment available to visiting industry researchers.
- Industry pays the university a set amount (360,000 yen in 1985) per researcher per year for the use of laboratory facilities at the university.[11]

An important aspect of Monbusho's program is that it has made an attempt to address one of the stickiest problems in university-industry cooperation (in both countries)—that of patent protection. Many companies in both nations have been reluctant to support research that might lead to profitable patents if they cannot be guaranteed the rights to the patents that result from the research. Monbusho's program allows industry to receive priority on patents resulting from joint research for up to seven years. Under Monbusho's joint research program, if joint university-industry research results in a patentable innovation, the university and company may apply jointly for the patent and negotiate a period for industry priority (not to exceed seven years). As of July 1988, 61 such patents had resulted from this program.[12] Nevertheless the ministry has also argued that *contract* research is *not* joint research and that patents resulting from contract research should belong to the government.

The JRDC has approached the patent issue differently, probably because its goals are different from Monbusho's. Established in 1961, JRDC's programs have been aimed more at efforts to exploit government-owned patents than at promoting new research. JRDC selects and supports companies to develop high-risk technology based in part on university research that might not otherwise be exploited. If the development is successful, the company is required to repay JRDC; if it is not, the company is under no obligation. Even in the successful cases, however, the company is *not* given

[10] "Japanese Links," *New Scientist* (4 August 1988), 28.

[11] National Science Foundation, Tokyo Report Memorandum, No. 69, 25 March 1985.

[12] National Science Foundation, Tokyo Report Memorandum, No. 158, 8 July 1988, 18.

the patent but is instead permitted to *license* it from JRDC. Half of the royalty goes to the owner of the technology; the owner may be a university or a government research institute.[13]

The patent protection issue is but one manifestation of industry's tendency to seek a "return on investment." This tendency has continued to create a ceiling on the degree to which industry is willing to contribute to university research in the United States and Japan. According to STA's 1983 white paper, in fact, Japanese industry has probably contributed as much as can be expected to basic research in Japanese universities, given the "return on investment" consideration.[14]

The "return on investment" question reflects a broader issue confronting both nations' attempts to improve university-industry relations—that of conflicting expectations. In both the United States and Japan, universities and industry seek cooperative research for different reasons. Universities are less concerned than industry about the applicability of the research for which they seek industry support. They also prefer to maintain the openness of their laboratories, whereas industry is becoming increasingly concerned about outside access to the university research it supports.

There is an additional constraint on Japanese university-industry cooperation. The lack of mobility induced by the lifetime tenure system in Japanese universities has created a situation in which there is little crossing of sectoral boundaries. Some Americans have argued that the Japanese have overcome this potential weakness with their plethora of information exchange organizations. By 1985, for example, the Japan Society for the Promotion of Science (JSPS) had formed 36 committees bringing industry and universities together to exchange information about various fields.[15] Another example is the Research Information Exchange Center, created in 1982 at the Tokyo Institute of Technology to promote integrated research between university researchers and those outside, promote contract research, and exchange information (in response to industry demands) through conferences and seminars. In addition there are a variety of committees organized by academic societies. They can be broken down into the following basic categories:

- Technical committees, for example, Japan Society of Precision Engineering's committees on Computer-Aided Design/Computer-Aided Manufacturing, Automated Assembly System, and Integrated Manufacturing System.

[13] Science and Technology Agency, *Research Development Corporation of Japan*, 1986.

[14] National Science Foundation, Tokyo Report Memorandum, No. 69, 25 March 1985, 3.

[15] National Science Foundation, Tokyo Report Memorandum, No. 69, 25 March 1985, 10.

- Subcommittees organized for special subjects, mainly for technological information exchange.
- Cooperative committees between industries and universities, usually paid for by industry. These committees, also primarily for technological information exchange, select new subjects to be studied each year.
- Research coordination committees, in which university and industry researchers exchange technological information about research work on specified subjects; for example, the Japan Society of Mechanical Engineering's committee on manufacturing engineering has existed for 15 years.

Nevertheless, according to former JSPS Director General Sogo Okamura, these exchanges do not always work the way they should because industrial competitors are often hesitant to speak freely in front of each other about what may become profitable technological developments.[16] In both nations, in spite of the common-sense argument that cooperative research can save money in the long run, the quest for profits may discourage cooperative efforts. According to Iwata, despite the growing number of university-industry cooperation agreements and the new rules by Monbusho, the greatest sticking point remains what to do when research results are ready to be published and patents applied for. Iwata suggests that these problems be worked out on a case-by-case basis.[17]

Finally, as noted above, the Japanese government has tried to encourage university-industry cooperation as a way of supporting more *basic* research. In fact, however, Monbusho seems to be encouraging university research that is *more* responsive to industrial needs. For example, Monbusho has created a category of research under the grants-in-aid program for "experimental (or developmental) research," and since 1983, has increased the number of industrial research leaders on the committees within Monbusho's Science Council that examine applications for special research grants.[18] In addition, grant proposals are still required to include "expected results," and there is considerable rigidity in the acceptable uses for grant funds. In theory it is the oft-criticized general funds that allow the most flexibility, since theoretically university heads can distribute them within the university as they see fit. The practice of using formulas to distribute the funds, however, limits the effectiveness of this flexibility.

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[16] National Science Foundation, Tokyo Report Memorandum, No. 69, 25 March 1985, 10.

[17] Kazuaki Iwata, *Manufacturing Engineering: University-Industry Coordination*, presented at the second Japan-U.S. conference on manufacturing research, July 11-14, 1988.

[18] M. Nishio, "New Movement in University-Industry Cooperation" (Tokyo: Ministry of Science, Education, and Culture, 1983), 6-7.

In keeping with its principle that the primary role of universities is education, Monbusho has stipulated that all joint projects be initiated by the university, in order to ensure that the research being pursued complements the university's primary function. According to Professor Gen Ohiwa of Toyohashi University of Technology, however, Monbusho's university-industry cooperation programs are *not* encouraging basic research, although they are educationally beneficial insofar as they allow students to see useful applications of their research.[19]

[19] National Science Foundation, Tokyo Report Memorandum, No. 69, 25 March 1985, 5-6.

6
Challenges

Despite differences in the research systems of the two countries, the United States and Japan are confronted with some similar challenges. Research in some of the newest areas of science and technology increasingly requires expensive, sophisticated equipment and more multi- and cross-disciplinary exchanges. Shorter lag times between "basic" research and profitable applications in many new sciences invoke quandaries about how to handle university-industry cooperation. Tensions between the principles that govern academic institutions—academic freedom and scientific exchange—and those that rule in the corporate world—return on investment and secrecy—plague both nations to varying degrees. Furthermore, increasing budgetary constraints call into question the role of government in resource allocation and science policymaking.

It is helpful to remember these "generic" challenges when considering the criticism that Americans and Japanese aim at their own respective systems. In addition, given the limited experience of Americans in Japanese laboratories and the strength of Japan in some fields of science and technology, the United States faces an urgent challenge in learning how to access and participate in Japan's research and development system. It could be argued that the challenge to Japan is also significant: to open its research and development system to meaningful foreign participation soon enough to meet rising expectations abroad that Japan will play a growing role in basic science and technology transfer.

The Japanese system faces a serious challenge in its efforts to improve basic research, efforts that must be made if Japan is to further scientific and technological progress, answer international pressure for it to contribute to

science, and encourage foreign participation in its research system. Recent Japanese proposals to create "centers of excellence" in Japanese universities are likely to challenge Japan's "democratic" funding system. Such centers will require concentrated funds and support, an idea that runs counter to the current proclivity to spread funds evenly—if thinly—among Japanese university chairs.

The organization and funding mechanisms for university laboratories in both countries create unique difficulties in meeting some of the other aforementioned challenges. Despite the strengths of the peer review system, some in the United States believe that overemphasizing a researcher's publication record in evaluation may create disincentives to pursue new and possibly risky research. Furthermore, the requirement for each researcher to seek his own funding has been criticized for creating too much (possibly counterproductive) competition and for encouraging U.S. researchers to respond to agendas other than those dictated by scientific research. In Japan, on the other hand, it is argued that the rigidity of the chair system, while good for education, stifles creative research. The Japanese system provides more security in the form of stable funding to the researcher, but leaves him few alternatives if his proposals are rejected. It also deemphasizes the contributions of younger researchers.

In both the United States and Japan, universities are organized by scientific disciplines in a classification system that may have outlived its usefulness. Both nations must find new ways to break down the barriers between traditional scientific disciplines. F. Karl Willenbrock, of the American Society for Engineering Education, has noted that the teaching and research components of engineering education increasingly require cross-disciplinary and cross-institutional ties. He claims that traditional disciplinary-structured engineering schools are not suited to some of the newer technological fields (e.g., advanced materials, computer technology, and biotechnology).[1] Similarly, a 1986 Office of Science and Technology Policy report recommended the creation of multidisciplinary science and technology centers as "much of the most exciting research to be undertaken in the future will not fall within the traditional natural science disciplines."[2] The establishment of Engineering Research Centers is an example of a recent attempt to respond to this need, as are multidisciplinary centers within some U.S. universities.

[1] F. Karl Willenbrock, "Remarks on Cross-Disciplinary and Cross-Institutional Relationships in Engineering Education," *Proceedings of the Fourth United States-Japan Science Policy Seminar* (Washington, D.C.: National Science Foundation, 1988), 67.

[2] Office of Science and Technology Policy, *Report of the White House Science Council: Panel on the Health of U.S. Colleges and Universities*, February 1986, 16.

In Japan, too, attempts are being made to respond to the rising need for high-quality, expensive, multidisciplinary research. Japan has created a number of new types of research organizations. Witness, for example, the rising acceptance of students graduating from technical colleges and the establishment of new types of institutions such as national interuniversity research institutes and Tsukuba Science City. The 12, soon to be 13, interuniversity research institutes have all been created in fields that require the collaboration of teams of scientists, and/or large, expensive facilities. These institutes are well funded and equipped and, in some cases, have attracted foreign researchers.

Another challenge faced by both nations is the requirement for increasingly complex, expensive equipment in some of the newest areas of scientific research. Both countries are seeking new ways to encourage cooperation between institutions and across sectors, in order to share the cost of equipment and facilities. In this sense, the Japanese grant system has been criticized as inefficient and wasteful. Because each chair receives an equal amount of the funds available for general research support, some funds go to faculty members who are not actually pursuing serious research. In addition, the system has encouraged a growth in the number of chairs and each chair's share has correspondingly declined. Monbusho has made attempts to address this issue with new types of competitive grants and programs that encourage university-industry cooperation. The same challenge in the United States has prompted some U.S. universities to make allocation decisions more centrally in some of the more expensive areas of scientific research.

The challenge of increasingly expensive equipment for leading edge technology exacerbates an ongoing decline in the quality and condition of facilities and infrastructure in universities in both the United States and Japan. As mentioned above, Monbusho's traditional allocation of resources may have tended to spread funds too thinly to be useful. Outdated equipment and rundown facilities are becoming the hallmark of Japan's most prestigious universities. In the United States, where only NSF offers general support to university research, real government support declined at a time when enrollments in U.S. universities were rising, leading to a similar situation.

At the same time, there is increasing controversy in the United States over the way in which federal grants are determined. With the increasing costs of research and declining federal budgets, researchers complain that too much money is being allocated to "indirect" costs; administrators claim they are not being fully reimbursed for indirect expenses; and the government worries that researchers are not being held accountable to the taxpayer for the money they receive. This had led to a growing tendency for the government to attempt to micromanage university research, a trend

that not only chafes university researchers, but creates more paperwork and red tape.

Although both the United States and Japan are encouraging increased industrial support for university laboratories, the need for *stable*, predictable funding has been cited as a potential problem of increased reliance on corporate funding. Admitting that U.S. budget cuts have at times created an atmosphere of unstable federal funding, critics claim that corporate funding can be even less predictable. Corporations are more likely to cut university funding than their own research staffs when profits falter.

Both the United States and Japan are also challenged by a lagging interest in graduate engineering education. Although it has been argued that Japanese universities could attract more graduate engineering students if they did a better job at integrating their educational and research roles, it appears that in both nations economics may have more to do with a declining interest in graduate school than a lack of opportunity to do research. In the United States, the disinterest in science and engineering has been linked to poor education in mathematics and the sciences as early as the elementary school level. There is, moreover, a large minority population that needs encouragement if it is to contribute to the pool of graduate engineers.

7
Implications for Foreign Access

The preceding pages have outlined some of the major similarities and differences between the U.S. and Japanese university research systems, as well as the major challenges each faces. With this understanding, some generalizations can be made about what a foreigner seeking access to the Japanese university laboratory system might expect. First, however, it is helpful to examine some of the facts about scientific exchange between the two nations. It should be noted that these figures, like many of the other figures used above, are subject to argument, as there is no general agreement on definitions. They can, nevertheless, serve as a point of reference.

In 1982-1983 there were 13,610 Japanese postsecondary school students studying in the United States (1,000 in engineering). Contrast this with the fact that in the preceding 20 years, no more than seven Americans were enrolled in Japanese engineering programs in any one year; most years saw none.[1]

In 1985, 20,000 Japanese researchers (including students) went to the United States while only 6,000 researchers from the United States and Europe combined went to Japan.[2] That same year 9,000 Japanese researchers went to countries other than the United States and Europe, while 33,000 non-U.S. and -European researchers went to Japan. In 1986,

[1] Lawrence P. Grayson, "Japan's Intellectual Challenge: The Strategy," *Engineering Education* (December 1983), 7-8.

[2] Genya Chiba, "Participation of Foreign Researchers in Japanese Research Activities," *Proceedings of the Fourth United States-Japan Science Policy Seminar* (Washington, D.C.: National Science Foundation, 1988), 168.

23,334 researchers went to the United States from Japan while only 3,633 went from the United States to Japan.[3]

There have been numerous attempts to explain the large gap between the number of Japanese researchers who come to the United States and the number of American researchers who go to Japan. Some attempts focus on cultural factors, others on structural and systemic factors; some focus on the United States, others on Japan. There is probably some truth to all of them, but organizational and societal factors will continue to play a role on both sides. With recent Japanese legislation that allows foreigners to work in national research laboratories and Monbusho rules that allow national universities to hire foreign scholars as regular faculty members, opportunities have increased but there remain cultural and other factors that limit full participation by the foreign researcher in Japanese laboratories.

Unfortunately, most explanations of the gap are anecdotal. There is, for example, little hard data on the number of U.S. researchers who have seriously but unsuccessfully attempted to gain access to the Japanese research system. Until recently, in fact, there were few indicators of even the number of American researchers who might be interested. The recent establishment of many new postdoctoral fellowships for Americans in Japan, and the response they receive, may help to answer this latter question. Although the American response (in the form of applications for the program) has so far reportedly been disappointing, Alexander DeAngelis, head of NSF's office in Tokyo, reported that this was because adequate information was not disseminated in a timely fashion. According to DeAngelis, NSF received over 1,500 inquiries about the program and applications were expected to increase in number.[4]

Despite the lack of hard data, some tentative suggestions and possible explanations will be put forth here for the purposes of discussion.

First, although Japan leads in many areas of technology development, there are few areas of *basic* research in which Japan commands the lead. Since universities are the loci of basic research in both countries, some argue that an American researcher has little reason to want to do research in a Japanese university laboratory. According to U.S. experts in fields such as optoelectronics, however, there are areas of applied research in which a few Japanese university laboratories are doing high-quality work at the forefront of their fields. In addition there are well-established cooperative research programs in some basic fields, such as controlled fusion. Nevertheless such

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[3]Tsusho Sangyosho [Ministry of International Trade and Industry], *Sangyo Gijutsu no Doko to Kadai* [Trends and Topics in Industrial Technology], 1988, 95.

[4]"Japanese Fellowships Go Begging Despite $2,000-a-month Pay," *Nature* 335 (22 September 1988), 287.

areas of excellence in Japanese university research continue to be relatively few.

An important factor in explaining the large number of Japanese coming to the United States is the Japanese perception of the value of human relations, connections, and first-hand experience. It has been argued that Japanese researchers come to the United States not necessarily to acquire knowledge or access U.S. research results, but to learn the American system and to make contacts. One indication of the importance to the Japanese of connections and understanding the system can be seen in Genya Chiba's (Research Development Corporation of Japan) recommendations for exchanges of administrative personnel as well as scientific personnel so that the United States and Japan can learn about the "business" aspects of research in each other's systems. Chiba holds that most current exchanges have been built on personal contacts.[5]

Thus, despite the fact that overall American university research is seen as of higher quality than Japanese, an American researcher may find at least two reasons for attempting to do research in a Japanese university laboratory. On the one hand, he may be in a field in which a particular Japanese university is doing world-class research. On the other hand, he may gain by increased understanding of the Japanese system and connections that he could make by working in Japan. The first category assumes that the American researcher has already learned of the Japanese laboratory where important research in his field is being conducted. While it is likely that a scientist actively pursuing research in his field would be aware of international developments therein, there is no formal network of informational exchange whereby he could learn of the most appropriate Japanese university laboratory for him to visit. Looking at the problem from a different perspective, Chiba notes that there are few mechanisms through which companies in Japan interested in hiring foreign researchers can find them; he calls for a system for exchanging information about available researchers and positions.[6]

If an American *does* decide there is value in entering the Japanese university laboratory system and decides where it would be most beneficial to work, there are still many obstacles to overcome, some inherent in each system and some that arise simply from differences in the systems. First, the American university researcher may find it difficult to find an

[5] Genya Chiba, "Participation of Foreign Researchers in Japanese Research Activities," *Proceedings of the Fourth United States-Japan Science Policy Seminar* (Washington, D.C.: National Science Foundation, 1988), 171-172.

[6] Genya Chiba, "Participation of Foreign Researchers in Japanese Research Activities," *Proceedings of the Fourth United States-Japan Science Policy Seminar* (Washington, D.C.: National Science Foundation, 1988), 171-172.

appropriate time in his career for research abroad. A young and untenured researcher may risk his career by going abroad. A tenured researcher, on the other hand, may have too many other obligations to the university. If the researcher depends on outside consulting income, he may face financial difficulty.

One of the first obstacles an American researcher will encounter, unless properly prepared, once in Japan, is a language barrier. Although many Japanese speak English, a smaller number speak it fluently. Even if the language barrier can be surmounted to enable everyday conversation, the foreign researcher will probably be frustrated at his inability to read the Japanese-language scientific materials surrounding him. Furthermore, because in some fields much written material is already in English, information exchange in those fields is enhanced by oral communication in Japan, a factor that can make American access to information difficult.

There are also a number of social differences that can create barriers to foreign participation. It has been argued, for example, that the Japanese group mentality places sharp boundaries between "insiders" and "outsiders" and that a foreign researcher is unlikely to be accepted fully into the laboratory of which he is only temporarily a part. Although this syndrome is for the most part based on Japanese politeness and respect for visitors, it nonetheless can be a difficult barrier to overcome. A recent article noted, "The image of the foreigner as a guest must be replaced with the more honest one of co-worker, whether in industry, the university, or in a national research agency."[7]

While the author of the above article recommends that Japanese research institutions offer longer contracts to foreign researchers, some Japanese have suggested that if U.S. companies were willing to permit their workers longer leaves there could be more exchange in programs such as ERATO. The lifetime tenure and employment systems in Japanese universities and businesses make it less risky for Japanese organizations to sponsor long-term research abroad; they can be reasonably assured that the employee will return to the organization and that the organization will thereby benefit from his having gone overseas. American companies and universities, on the other hand, have to consider whether an employee they send overseas will return to work for another organization.

One, but by no means the only, aspect of the degree to which a foreigner is accepted into the "fold" may be the degree to which he or she is willing to adapt to the ways of Japanese society. The workplace in Japan often takes the place of one's family, and acceptance in the workplace may require sacrificing much of one's private life. An American who is

[7] Masanori Moritani, "Foreign Researchers Still Face Barriers," *Tokyo Business Today* (February 1988), 40.

accustomed to maintaining a division between his private and professional life may find it difficult to adjust to working in Japan; after-hours socializing is a normal part of the working life of most Japanese.

An American researcher in Japan must adjust to differences between the way Japanese and American university laboratories are organized. Relief from funding pressures may come at the cost of total research freedom. Although a foreigner may not be bound by the hierarchical constraints on Japanese researchers, the Japanese group may be less willing to accept a new approach to a problem if it is suggested by a junior researcher. Perhaps most important, the language barrier can prevent effective use of equipment if a foreign researcher is unable to read instructions, and preclude full exchange of views with other researchers so important to collaboration. Depending on the personality of the researcher, cultural and organizational differences may present opportunities as well as difficulties.

Although the Japanese government has made efforts to encourage industry-university cooperation, and although there are numerous informal channels of information exchange between universities and industry, it is doubtful that a foreign researcher entering the Japanese university laboratory system would have extensive access to industry laboratories. It is likely that he would make connections through ongoing cooperative research projects and also probable that he would be permitted to attend informational exchange meetings in some cases (assuming he could follow them in Japanese). His ability to make such connections would, in all likelihood, depend on the individuals at his host laboratory and whether they were willing to introduce him to their networks.

Finally, if a foreign researcher enters the Japanese university laboratory system, is accepted, and is able to take credit for a discovery, he may wonder whether the reward system works as it does in this country, via the granting of a patent. It is only recently that outside organizations have been able to have priority in patenting of discoveries made at a national university laboratory. Traditionally, these patents belonged to the government; the government has, in the last few years, allowed companies supporting research in national university laboratories to have patent priority for a maximum of seven years. This move was made in an attempt to encourage private industry support of university research. A foreign researcher working in a university laboratory in Japan can probably not expect anything more than what has been offered to Japanese industry. U.S. industrial researchers have been able to apply for patents on discoveries made in Japanese universities.

8
Conclusion

The above discussion points to the relative difficulty foreign researchers may face in working in Japanese university laboratories. None of these obstacles is in itself overwhelming, and a number relate more to the preparation and motivation of the foreign researcher than to barriers consciously erected in Japan. Nevertheless, the comparatively small numbers of Americans who have worked for extended periods in Japanese university laboratories suggests an urgent need for individuals and organizations in both countries to create significant new opportunities, opportunities that will ultimately benefit both countries. Absent such efforts, perceptions of a "one-way flow" are likely to persist and color the policy debate.

Appendix
Keynote Addresses

The U.S.-Japan Dialog on the Working Environment for Research in Universities was cochaired by Dr. Roland Schmitt, president of Rensselaer Polytechnic Institute and formerly chief scientist at General Electric, and Dr. Sogo Okamura, professor at Tokyo Denki University and former dean of the School of Engineering at Tokyo University. The workshop, held at the Beckman Center in Irvine, California, was opened with keynote addresses by Drs. Schmitt and Okamura on January 9, 1989. The texts of those addresses follow.

KEYNOTE ADDRESS

Roland Schmitt
President
Rensselaer Polytechnic Institute

We are embarking on an unusual activity. Our objective is to see if we can find new ways of cooperating in research to the benefit of both our nations. Now, we already have at least four decades of evolving relations in this arena; so it may seem curious that the topic is suddenly of such great importance. But the reason is simple. Our two nations have entered a new era of comparative strength and comparative advantage in our respective capabilities in high technology industries and in research in natural sciences and engineering. In the last two decades Japan has

emerged as a predominant economic force based in no small degree on its ability to develop, produce, and market technology-intensive products. The task we have in the next two days is to see how this situation affects the modes of cooperation between our nations in university research.

Limiting ourselves to a discussion of university research means that we are ignoring some of the most important issues of reciprocity and parity between our nations, although later workshops will cover them. The distribution of research capability among the various institutions—universities, industries, and government labs—is different in our two nations. Thus the improvement of productive research relationships between our two nations goes much beyond the topic of this workshop. We might agree on new cooperation in university research that would not, in fact, contribute a great deal to the solution of the broad problem. So I would first like to address some of the broader issues that surround that of university research.

We should start by reviewing some of the differences that now exist. Graduate education in universities is on a larger scale in the United States than in Japan. In 1983, the number of Ph.D.s in engineering awarded as a result of graduate work in universities was 489 in Japan, 2,781 in the United States. Masters degrees, similarly based, were 7,703 in Japan, 18,642 in the United States. In this same year, the number of bachelor's degrees awarded in engineering were about the same in each country, about 70,000. These differences are a reflection of the fact that Japan has many fewer graduate students in total in its university system than the United States.

The differences in scale of graduate academic research in the two countries may, in part, cause the imbalance in flow of research workers between the two. In 1986, for example, 23,334 Japanese researchers came to the United States while only 3,633 U.S. researchers went to Japan. The exchange of researchers takes place between all institutions, not just universities. But, any way you look at it, the flow of scientific and technical people and information is very one-sided today. The condition reflects the realities of the past, however, not those of the present and future.

Japan's strategy for technical knowledge has been similar to its strategy with other resources. Being a land of limited natural resources, Japan has learned to live and to prosper by its wits and its energy. It imports resources, it adds value, it uses and exports the resulting products. It has done the same thing with scientific knowledge; importing it, adding value, using and exporting it in products. But, importing knowledge is different from importing coal, iron ore, or oil. Knowledge is brought back by people, not in cargo ships or tankers. Thus, Japan has sent legions of people abroad to acquire and bring back this knowledge.

The United States followed a similar strategy in the last century and early part of this one. As those people who had gone abroad from the United States to acquire scientific and technical knowledge returned from

Europe, they brought back new capabilities as well as new knowledge. And these capabilities found a rich cultural soil in which to grow and prosper—our strong heritage of exploration, of moving into new geographical frontiers, and of pioneering. Our propensity for pioneering, added to our new found capability in science and technology, resulted in an outpouring of new discoveries, inventions, products, and industries, beyond those of any prior period of history.

Japan, too, with its returning researchers has brought back to its shores capabilities as well as knowledge. But those capabilities, lodged in a different cultural environment, have produced a different result. They have produced an outpouring of innovative improvements, modifications, and new generations of products that have captured dominant positions in world markets. In a sense, the cultural propensity of Japan for perfection, for step-by-step improvement, was ideally suited for the style of innovation needed in these phases of industrial evolution.

Today, as Japan talks of moving more and more toward basic research, I believe it is an open question of whether or not the results will be similar to the earlier experience in the United States, given the quite different cultural soil nurturing the efforts. I will be interested in hearing the views of our Japanese colleagues.

Another key question that must be answered is "Where will Japan strengthen its capability in basic and/or pioneering research?" Will it be primarily in academic institutions or will it be in government labs or industry? Attempts are being made on all these fronts but it is not clear that universities will be the principal locus of growth in such research. We need to hear from our Japanese colleagues on this. The answer will greatly affect the conclusions of this workshop.

The broad issue that confronts us today is how to ensure appropriate scientific and technical exchange between our nations, and the specific issues of this workshop must be addressed within that context.

The toughest part of this challenge may rest with Japan. U.S. institutions generally, and U.S. campuses particularly, have a long history of being multinational, multicultural, and multiracial. Japanese institutions do not. As Japan's science and technology becomes ever stronger, it will have to strive more and more vigorously to ensure that foreign nations have ample opportunities to participate in its system as full partners, as equals. In past decades, Japan has benefited from its access to the research and academic institutions of the United States and Europe. If Japan now becomes a leader in generating new knowledge, inventions, and discoveries with commercial potential, it will want to reciprocate with open laboratories, open faculties, and open institutions. The Japanese have had over three decades of experience in extracting knowledge from Western institutions

that welcomed them. During most of that time there was no strong reason for the Western nations to ask or pursue reciprocity. Today, there is.

The present imperative for the West to learn from Japan has sprung on us quickly and with full force. We cannot take three decades to learn how to do it. Moreover, the West is faced with cultural and institutional traditions in Japan that are not congenial to foreign attempts to become a part of their fabric. Alex DeAngelis, head of the National Science Foundation's Tokyo Office, has remarked on the "sense of distance and separateness toward outsiders which is . . . a longstanding motif of Japanese society." We have a great challenge and we do not have a lot of time to resolve it.

DeAngelis points out that for all of the extensive courtesy accorded guests in Japanese institutions, "as long as [this] courtesy implies always treating outsiders as 'honored guests,' who by definition deserve better and special treatment than everyone else, then courtesy will also be used as a tool to keep people at a distance." Thus the job is daunting but immeasurably important. And it must be judged by results, not by expressed intent! It will not be sufficient to announce programs that seem to be responsive if they do not in fact work. Good intentions are not enough. Japan and the United States together must find and promote programs that work because such programs will benefit us all in the long run.

This meeting today is one of a number of new activities that have grown out of dialog between the U.S. Academies and the Japan Society for the Promotion of Science. It is also in the spirit of the 1988 U.S.-Japan Toronto Summit agreement for further cooperation in science and technology. Getting started on these initiatives on both sides of the Pacific is important and we should strenuously try to make them work. But, should any of them fail, we cannot allow anyone to conclude that nothing will work. Instead, we must keep trying: the task is to find programs that do work.

The effort will certainly be beneficial to Japan's own interests. Appropriate steps to further internationalize its research system, and especially the academic research system, will also strengthen those systems, just as they have strengthened U.S. research systems. Some of the factors commonly cited as impediments to a strong academic research system in Japan—such as the dominance of the *koza* or chaired professor, especially in the national universities—will have to be corrected. A more congenial environment for bright, young researchers—such as Professor Tonegawa—will have to be established. Greater accommodation of interdisciplinary research, easier entry into entirely new areas of research, and more flexibility in industrial interactions are desirable.

Thus, the imperatives of internationalization and those of a strengthened capability in basic and pioneering research are compatible and synergistic. Alex DeAngelis, again, has summarized the objective well in saying that "the primary goal should not be to attract foreigners per se but to

create a research environment which in and of itself will naturally attract the best minds from all over."

A strong system of research that is accessible to foreigners, and that foreigners participate in meaningfully, implies dealing with the language issue. I believe it can be handled by additional language courses in both the United States and Japan. Far more important is the issue of where Japan's research strengths will grow. If basic, precompetitive research grows mainly in industrial labs or in programs, such as the International Superconductivity Technology Center (ISTEC), that are expensive and inaccessible to a broad range of U.S. researchers, including academics, reciprocity will be hard to achieve. Thus it would seem that strengthening an accessible academic research system should be a high priority—and it should be an academic system tightly linked to industry. I will give other reasons in a moment for why I think this is so.

The alternative—growing capability in inaccessible institutions—could have a bad effect on both of our countries. Let us imagine, for a moment, that at some future time the balance of payments for royalties and license fees on intellectual property should reverse, with Japan becoming a net exporter in this segment as it is in so many technology-based products. And suppose this happens without achieving reciprocity in access to research. Should that come to pass, I fear there would be a political backlash in the United States that would make it difficult to maintain free, open access to our universities—a development adverse to both our countries.

This brings me to the subject of our own research universities. What changes and issues are they facing and what will be the effect on future exchanges between the United States and Japan? In fact, U.S. research universities face a future of immense challenges and I am not confident that they are yet prepared for it. The future will be less benign toward these great institutions than has the past. And the fundamental reason is that resources—human and financial—will not be as plentiful as in the past. Moreover, many universities are ill-prepared, in governance, attitude, and management, to meet this future. Today, I cannot begin to cover the full range of issues implied by these brief comments, so I want to limit myself to the issue of human resources.

Today the number of high school graduates in the United States is dropping—by one-third over a decade in some parts of the country. In spite of this drop, higher education in the United States has been heartened by growing applications to college, indicating a higher fraction of high school graduates are going to college. That is fine for the moment, but there are limits to that solution of the problem. For us here today, the more serious problem is that fewer and fewer of these high school graduates express an interest in science and engineering. Among college freshmen, those interested in a science major have dropped by one-third over the

past two decades. And more recently, those interested in engineering have dropped—by one-fourth between 1982 and 1987. So even today, in a number of schools where total applications are still growing, applications for science and engineering are dropping. Thus we face the prospect of a diminishing fraction of a diminishing supply of students going into science and engineering.

And once in the "pipeline," as we call it, the attrition rates are high, especially at the bachelor's level. We thus have too few domestic graduate students in science and engineering and have come to depend on a strong flow of foreign nationals for our graduate student population. And this has now carried forward to the stage of young faculty and young researchers in our industrial labs, where we are more and more dependent on foreign born individuals to fill these. For example, by now, 50 percent of U.S. engineering faculty below the age of 35 are foreign born. In fact, the United States has become dependent on the import of technical talent.

This situation is getting a fair amount of attention these days, and it may well be that, within the next few years, U.S. educators will develop—and U.S. legislators and industry fund—some good programs to change these trends by increasing the numbers in the science and technology "pipeline." But even the most successful programs will not turn the situation around quickly enough to eliminate the dependency in the near future.

The net effect of this is that U.S. research universities must and will continue to strongly welcome foreign students. And they have been coming in growing numbers from the Pacific Rim—especially at the graduate school level. As recently as 1980, the number of foreign undergraduates in U.S. universities outnumbered foreign graduates by two to one. By 1987, the number of foreign graduates exceeded undergraduates by 14 percent. This shift has been driven largely by the influx of Pacific Rim students while students from Africa and the Middle East have dropped. Thus, competing with any move to limit access to U.S. universities by noncooperating foreign countries will be the economic and human resource imperatives I have described. How would the U.S. balance these opposing forces, should it come to pass? It probably depends on how the public at large and its elected representatives feel at the time. In the extreme case one can imagine the equivalent of trade negotiations to determine bilaterally, country by country, what the exchanges will be. It is a situation that I hope we can avoid.

Finally, among the many other trends on the U.S. academic scene that might affect future exchanges between our nations, I want to dwell on one: the relationships between U.S. universities and U.S. industry. Support of research in U.S. universities by industry has steadily grown, from about $200 million (1987 dollars) in 1973 to over $700 million, or from 3 percent of academic research and development (R&D) to over 6 percent in 1987. Although this fraction is still small, its growth is indicative

of its importance to industry. Moreover, the magnitude of the support is far from representing the whole of industry-academic linkages. Much government supported research on campuses—such as that of the U.S. Department of Defense—is strongly linked to industry. And universities have been the source of much entrepreneurial activity—campus-originated ventures, again R&D for industrial development.

For a moment I want you to think about this campus-based, industry-linked R&D as America's form of cooperative industrial R&D. I know that is perhaps an oversimplified point of view, but bear with me for a moment. U.S. antitrust laws severely limited the amount of direct, precompetitive cooperation among U.S. firms. But corporate sponsorship of academic research, the formation of industrial affiliate programs on campuses, the use of professors as consultants, sending industrial researchers back to campus, and spinning off entrepreneurial venture firms are all legitimate activities. They have thus constituted the U.S. form of cooperative industrial R&D. It has several notable characteristics: it is relatively open with only modest direct advantages to the sponsors and participants compared to others; it is relatively inexpensive to participate; and it is not usually highly focused.

The Japanese forms of cooperative industrial R&D have been quite different. Although such programs have not been the dominant factor in Japanese success that many in the United States believe, there have been productive instances. In part, cooperative programs like the Very Large Scale Integration (VLSI) effort that ran from about 1976 to 1980 provided Japanese industry with research results that U.S. firms often get from academic research in the United States. But, in contrast with the relative openness of U.S. R&D, the Japanese programs were closed. As I have already remarked, the current version of such a program, ISTEC, though open is expensive.

This picture is another example of asymmetry in our systems that we will have to deal with in promoting further exchanges. What does the future hold? I believe that cooperative industrial R&D in the United States will grow for two reasons: first the antitrust laws are now more congenial to such enterprises and, second, the potential shortages of human resources for R&D in the United States may give additional impetus to such cooperation. Indeed, the trend has begun, with MCC and SEMATECH being prime examples.

I hope that in the United States, this growth of cooperative industrial R&D will continue to be tightly coupled to university research because the linkage enriches the campus environment and the education of our students. It will also help solve the shortage of human resources. But we are going to have to be inventive in finding ways to preserve these linkages because industry will be moving into areas of cooperation in which the

complete openness of traditional campus research may not be appropriate. We also need to make sure that this growth is not at the expense of the past productive arrangements and in fact adds to them.

But, either way, U.S. industry may look more closely at Japanese participation in such programs. If it is not different from the past, and we do not achieve reciprocity of R&D exchanges in some other way, then we are going to have problems.

I would like to suggest that there are two Japanese strategies that would contribute productively to establishing a balance. One, of course, is to strengthen academic research in Japan, and, as Alex DeAngelis suggests "the primary goal should . . . be to create a research environment which in and of itself will naturally attract the best minds from all over." Doing this would inevitably increase the number of U.S. researchers in Japanese universities. But there may be a complementary way of partly affecting a more equitable flow of R&D between the two countries and that is through the kind of people sent from one country to the other. Heretofore, Japan has sent researchers to the United States in large numbers who primarily intend to learn new things and bring new research results back to Japan. But Japan might help equalize the flow by sending senior researchers in larger numbers to U.S. universities—people who could bring the most advanced results of Japanese research from industrial and government labs *to* U.S. campuses. U.S. universities would be an effective way of disseminating such expertise. This would be a means of partly equalizing the flow of research that could be productive almost immediately.

In conclusion, I have tried to present the challenge facing us today as we seek ways to increase the equitable exchange of academic researchers. I have also looked at a couple of key features of the U.S. academic scene that bear on this exchange and have made a couple of suggestions. The challenge facing us is great, but it matches the benefits that would ensue from success. If we and the subsequent workshops in this series come forth with new ideas to improve the exchanges between our nations, both of us will benefit immeasurably. If we fail to address the present issue and fail to achieve the result we all desire, the consequences will be bad for both of us. Failure will cause additional walls to be built around the R&D of each country. This would be bad for both of us. We must not fail.

KEYNOTE ADDRESS

Sogo Okamura
Professor
Tokyo Denki University

I am pleased to be addressing such an important and engaging subject—important because it contributes to human development, engaging in the sense that it needs more attention so that research can flourish in a fertile environment. To help us in our discussion of the differences and similarities in the working environment for university research in Japan and the United States, I would like to outline some aspects of the research environment in Japan, including government policies, the culture of academic research, the research funding system, university-industry relations, and international cooperation.

SCIENCE POLICY AND UNIVERSITY RESEARCH IN JAPAN

Japan's education system was reformed after World War II. Since then, economic development has brought about the expansion and popularization of higher education. Increases in the number of students in higher education have not only elevated Japan's intellectual level, but also contributed to training the manpower required by industry. As higher education grew more popular, what were once research institutions increasingly became educational institutions. In its efforts to expand higher education, Monbusho (the Ministry of Education, Science, and Culture) focused more on establishing new universities in provincial areas than on promoting research excellence. Through this policy several universities that were commonly acknowledged as centers of excellence before the war suffered reductions in financial and human resources.

Moreover, Japanese society's strong feelings against discriminatory funding have created a system in which all universities are treated equally. We cannot, therefore, classify Japanese universities as "research" or "teaching" universities. As a result, university faculty are expected to engage in research (considered an integral part of their activities) with "outdated equipment and rundown facilities," and diluted research funds.

As of May 1987, there were 475 universities in Japan. Of these, 96 were national universities established by Monbusho, 37 were public universities set up by prefectural or municipal governments, and 342 were private institutions. Of the 475 universities, 288 had graduate schools, 198 of which included a Ph.D. program.

Monbusho's Science Council has held intensive discussions about improving the working environment for university research. These discussions resulted in two reports. *Basic Policies for the Promotion of Science* (October 1973) covered:

1. improvement and reformation of the research system,
2. expansion of research funding,
3. development of research manpower and research support systems,
4. promotion of international cooperation, and
5. improvement of the science information system.

Basic Policy of and Measure for the Improvement of the Scientific Research System (February 1984) included:

1. promotion of important science projects,
2. development of research manpower,
3. measures to meet the demands and expectations of society for university research,
4. promotion of international cooperation, and
5. promotion of the humanities and social sciences in Japan.

Following these recommendations, an attempt was made to promote centers of excellence in university research. It was, however, very difficult to distribute the limited financial and human resources to many universities and the attempt failed. Nevertheless, one of the most successful projects, I believe, was the establishment of the National Interuniversity Research Institutes. Most of these institutes focus on the natural sciences, particularly the so-called "big sciences" such as accelerator theory, space, fusion, and Antarctic research, but creative research in engineering has been rather ignored.

CULTURE OF ACADEMIC RESEARCH IN JAPAN

Many hypotheses have been offered from various fields about Japanese "creativity":

- Neuropsychology—the Japanese brain and cognitive patterns may not be suited to creative research.
- Psycholinguistics—the Japanese lack of creativity may stem from the Japanese language itself.
- Cultural anthropology—the Japanese agrarian village mentality discourages the strong-willed pursuit of individual opinions because rice farming was always done as a group. Moreover, ancient belief structures were polytheistically ambivalent and tolerant of other beliefs.

Rather than detail these and other hypotheses since I am not really versed in these areas, I would like to mention that the Japanese people are, by nature, fond of basic research. During the Edo period, which preceded the Meiji Restoration in 1868, the Japanese government advocated a strict isolationist policy, and international exchange of any kind was practically nonexistent. Japanese academic circles were completely cut off from scientific developments abroad. Nonetheless, the Edo period saw the growth of some branches of domestic science. Japanese mathematics or *wazan,* for instance, showed vital progress. Advanced formulae in differential and integral calculus as well as analysis by matrix were invented completely independently from Western mathematics, even before the discoveries of Newton and Laplace. Moreover, some of these advanced mathematics, such as calculation by progression, were learned simply for pleasure.

With the Meiji Restoration, however, the Japanese government realized the importance of science and technology to industrialization and emphasized applied research and development (R&D). Thus it has only been over the relatively short period of the past 100 years that the Japanese have placed high priority on applied research and development—a minor interlude in the whole history of Japan. Even today, pure basic research is considered to be more noble than efforts in applications.

BASIC PRINCIPLES OF JAPAN'S RESEARCH AND DEVELOPMENT POLICY

Japanese industry has recently made remarkable progress, proving its ability to adapt to changing demands and making the most of opportunities in the world market. This progress, however, has brought about serious trade friction. Japan has been criticized for using foreign technology in the manufacture of new products without contributing to the store of human knowledge through basic research. It is only fairly recently that the Japanese government has come to recognize the importance of basic research and the need for international cooperation in such endeavors.

The basic principles of Japan's current science and technology policy are founded on a cabinet resolution of March 1986 called "General Guidelines for Science and Technology Policy." This resolution was based on the recommendations of the Council for Science and Technology in a report entitled *Comprehensive Fundamental Policy for the Promotion of Science and Technology—Focus on the Current Changing Situation from a Long-term Perspective* of November 1984. The Cabinet guidelines stressed three major objectives:

1. promotion of highly creative basic research,
2. development of science and technology in harmony with humanity and society, and

3. promotion of international activities.

What will this mean in practice? The financial and human resources devoted to research and development reveal much about Japan's international position in science and technology. Japan has shown tremendous growth in both R&D expenditures and personnel. Japan currently spends 8,120 billion yen on R&D, a threefold increase over 10 years ago. As a percentage of gross national product, Japan's total R&D expenditure levels have risen annually, reaching 2.8 percent in 1986, approximately equal to or a little higher than that of the United States.

A gap remains, however, between the ideals and principles set forth in the cabinet guidelines and their realization. I hesitate to say that the establishment of basic research systems in Japan will go smoothly. The Japanese government has a far smaller share of national R&D expenditures than do the governments of the United States, West Germany, France, and the United Kingdom. Moreover, the ratio of public funding to total R&D expenditure has been declining in Japan.

The number of researchers in Japan appears to be rising, but statistical data on the number of researchers expressed in full-time equivalence is not available in Japan. It is, therefore, difficult to compare the Japanese R&D personnel situation with that of other countries. University faculty in Japan are expected to conduct research as part of their professional activities. Accordingly, even foreign language teachers who teach beginner's courses and could hardly be expected to conduct research are customarily counted as full-time researchers. Consequently, the number of university "researchers," especially in the humanities and social sciences is probably highly inflated.

Industry, higher education, and national and public laboratories claimed approximately 61 percent, 31 percent, and 8 percent, respectively, of the total Japanese research personnel in 1986. The number of R&D scientists *is* increasing, but nowhere so much as in the private sector.

Finally, the Japanese government's budgeting system is extremely rigid. Even requests for basic research funding must be accompanied by concrete specifications of expected results. This system places a great burden on the researcher.

Thus it seems that the Japanese government is making empty promises to strengthen basic research systems with no real intention of implementing them.

National universities and related research institutes are funded by Monbusho, which covers expenses for personnel and management, research and education activities, and the construction of research and education facilities. Research and education activities are funded by general funds or

specific funds, such as special research funds for facilities and equipment, research grants, and so on.

The general funds system has sometimes been criticized as inefficient and wasteful. "Since each professor receives an equal amount of funds available for general research support, some funds go to faculty members who are not actually pursuing serious research." General funds are, however, more flexible than specific funds, which must be used as set forth in the proposal submitted to Monbusho. It is extremely difficult to adjust specific funds to research progress. Moreover, although general funds are allocated to universities according to a standard formula based essentially on the number of researchers and the nature of the *koza*, universities *can* distribute them to faculties, departments, or individual staff members, based on their activities. In practice, however, because it is difficult to evaluate research activities across disciplines, general funds are most commonly distributed according to a standard formula. This system poses another difficulty in promoting research excellence.

UNIVERSITY-INDUSTRY RELATIONS

About a hundred years ago when Japan started to devote herself to industrial development, highly educated researchers were hard to come by. Most of them were employed by national universities and government research institutes rather than industry. In addition, university professors and government officials had more opportunities for study abroad than did engineers in industry. Therefore, industry relied heavily on universities for scientific knowledge. In those days, university engineering professors were real leaders in their fields, not only in theoretical work but also in practical matters. They maintained close relations with related industry and were often asked to design and make specifications for new products.

After World War II, however, this changed. Too many universities flourished in Japan, and the authority and social status of university professors diminished. Furthermore, Japanese industry developed its own research and development activities, which eventually became remarkably strong. Japanese industry thus became independent from the research work of the universities. In addition, university professors became more immersed in theoretical work and less familiar with practical affairs. This attitude led to the disintegration of university-industry cooperation, particularly university-industry research interaction.

It is also noteworthy that the innovation process in Japan is somewhat different from that in the United States and Europe. In the United States and Europe the innovation process is usually considered a linear process. In Japan, however, it is seen as a kind of network. In either case, universities are responsible for basic research while industry engages in development,

production, marketing, and distribution. In the United States and Europe, there is a tendency on the part of industry to expect the innovation process to begin with the results of basic research conducted by universities and research institutions. In Japan, the innovation process does *not* always start in the research stage; it often begins in development, production, marketing, and distribution. When industry recognizes the need for research during the marketing or production processes, for example, it immediately launches a new research project to solve the problem; it does not have time to seek assistance from university researchers. This approach to the innovation process may be one reason for the unexpected lack of university-industry research cooperation in Japan.

Although formal cooperation between universities and industry is very poor in Japan, significant collaboration *has* been conducted indirectly or informally. Quite a few university professors become project leaders, advisers, or investigators in government-sponsored projects or join academic society research committees where university and industry researchers conduct research jointly. Industry also asks university professors for free advice. In return, industry provides generous support to university professors by making experimental instruments, research devices, and other materials available free of charge or at reduced prices. Finally, since a number of high-level managers in industry are graduates of engineering schools, they can easily collaborate informally with their former professors.

These forms of cooperation, however, are only available to well-known professors from first-class universities. In addition, rapid changes in the attitudes of young people in Japan may make cooperation between universities and industry even more difficult in the future.

Many opinions and recommendations about how to strengthen the linkages among universities, industry, and research institutions have been made, and the government has tried to improve and expand cooperation between universities and industry. Unfortunately, however, I must say that systematic cooperation between industry and universities in Japan lags behind that of the United States.

INTERNATIONAL COOPERATION

In looking at recent reports and recommendations made by various organizations, both in government and the private sector, there is at least one common element—the emphasis on the importance of international cooperation. Japan once more is behind in efforts at international cooperation. In order to carry out international cooperation successfully, I believe Japan must become more sensitive to and develop a better understanding of the fact that the world is made up of different societies, cultures, languages, beliefs, historical backgrounds, traditions, and so on. Bearing that fact in

mind Japan must maintain funding mechanisms that are flexible enough to be useful in pursuing a program of international cooperation.

Japan's international relations started only about a hundred years ago. Today, she still lacks experience in international society. We should strive to overcome this handicap and to learn from the United States. We would also hope that the American people will keep an open mind and be sympathetic to the fact that few Japanese get an opportunity to interact with foreigners.